

# Summer Feeding and its Relationship with Reproductive Parameters of Cod (*Gadus morhua*) on Flemish Cap

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## Abstract

Data on cod (*Gadus morhua*) were obtained from random stratified bottom-trawl surveys carried out on Flemish Cap (NAFO Div. 3M) in July and August 1989 and 1990. Stomach contents of 1 182 cod in 1989 and 530 in 1990, classified by age groups, were studied. The empirical relationship between the stomach Fullness Index (FI) variation by age and year-class abundance variation were analyzed. Ingestion of Hyperiidæ (mainly *Themisto* sp.) and young redfish (*Sebastes* sp.) were mainly responsible for FI variation in all year-classes in both years. The relationships observed were used to propose a model which links several biological parameters of the Flemish Cap cod population.

**Key words:** Cod, *Gadus morhua*, feeding-abundance relationship, NAFO Division 3M

## Introduction

It is well-known that the qualitative and quantitative composition of fish diets is important to the growth, maturity and fecundity changes in fish, but the many interrelationships are not clearly understood. Interactions with other species have often been studied. Predation by Flemish Cap cod on smaller cod and redfish have been found to produce variable mortality in small redfish, and contribute to variability in year-class strength (Akenhead, MS 1978; Lilly, 1987).

It was noted in the Scientific Council Reports (NAFO, 1983): "Average length-at-age for cod increased considerably in recent years... . It was noted that on a qualitative basis, the changes observed in average length-at-age correspond to the perceived reduction in stock size. The stomach fullness index for cod <60 cm long was considerably greater in 1983 than in 1978... . The relationship between increased food consumption and a decrease in stock size is not known, but it deserves careful investigation".

In this study the summer feeding of cod (*Gadus morhua*) is studied in relation to age and year-class abundance variations on Flemish Cap (NAFO Div. 3M). Although the data were limited to two bottom-trawl surveys, the stomachs were sampled in summer. These summer months correspond to the period of highest feeding intensity (Turuk, MS 1981), and it is known that the diet is not very different during the rest of the year (Albikovskaya and Gerasimova, MS 1989).

## Materials and Methods

Cod sampling was carried out during two summer random stratified bottom-trawl surveys on the Flemish Cap (NAFO Div. 3M) in July and August 1989 and 1990 by the research vessels *Cryos* and *Ignat Pauliuchenkov*, respectively (Vazquez, MS 1990 and MS 1991). In 1990, a few pelagic trawls were carried out and a few cod fry were caught.

A total of 1 182 in 1989 and 530 in 1990 cod samples were collected and studied. The total length of each cod was measured to the nearest cm and each individual was weighed to a precision of  $\pm 2$  g. The otoliths were extracted for age determination in the laboratory. The cod were then classified by age groups.

The cod stomachs were collected and frozen on board. Stomach contents were examined in the laboratory and the food components separated and identified as far as possible. Items in each taxon were placed briefly on absorbent paper to remove excess liquid, and then weighed to a precision of  $\pm 0.01$  g.

The prey occurrence index, the Simpson diversity feeding index and the diet overlap index were calculated in a previous study (Paz *et al.*, MS 1991). The cannibalism rates were studied earlier (Paz *et al.*, MS 1989). The relative quantity of food in the stomachs and the relative importance of individual prey types was assessed using two indices:

1. The gravimetric index where the total weight of specific prey in all stomachs was determined as a percentage of total weight of all prey.

2. The stomach fullness index (FI) was obtained by calculating the mean Total Fullness Index

$$TFI = \frac{1}{n} \sum_{f=1}^n \frac{\text{weight of stomach contents of fish (f)}}{\text{length of fish (f) exp 3}} \times 10^4$$

(TFI):

where  $n$  is the number of stomachs examined, and the mean Partial Fullness Index of prey ( $p$ ) (PFI ( $p$ )):

$$PFI = \frac{1}{n} \sum_{f=1}^n \frac{\text{weight of prey (p) in fish (f)}}{\text{length of fish (f) exp 3}} \times 10^4$$

## Results

The number of stomachs collected in relation to the age distribution and the mean TFI values including empty stomachs by age for 1989 and 1990 are given in Tables 1 and 2. In both years the diet consisted primarily of two categories: Hyperiidæ (mainly *Themisto* sp.) and redfish (*Sebastes* sp.). The high percentage of these two food items are shown, where the PFI and the TFI are given for comparison. The high percentages indicate that the TFI variations depend on basically two food items, and this relationship represents a very simple feeding pattern (Paz *et al.*, MS 1989).

In the 2 years sampled, the variation of the TFI by a single age group was calculated as the quotient between the mean TFI at the same age for each year, e.g. at age 3 the quotient of  $1.661/0.941 = 1.77$  is the variation of the TFI between 1987 and 1986 cohorts.

The variation of abundance between the 1986 and 1987 cohorts was evaluated as the quotient of the natural logarithms of population numbers for age 2 and 3 in the 1989 survey, and age 3 and 4 in 1990. The mean of both values was used. The same process was used for the calculation of the year-class variation between other cohorts. The results

	Year-classes				
	1982-83	1983-84	1984-85	1985-86	1986-87
Year-class variation	1.50	1.40	1.10	0.98	0.74
TFI variation	1.22	0.91	1.61	1.32	1.77

are as follows:

The regression line resulted in a negative slope (Fig. 1). Although the regression was not significant

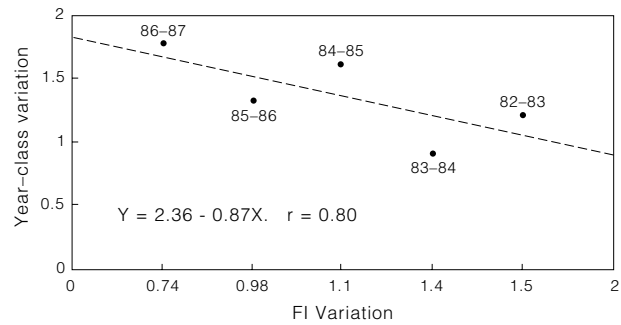


Fig. 1. Year-class cod increment and fullness index variation by cohort.

at  $P = 0.05$ , this was considered an empirical relationship between an increase in food consumption as year-class abundance decreased. These numbers were considered to provide a basis for assessing density dependent growth in Flemish Cap cod. With regard to the relationships between growth and year-class fluctuations, a negative relationship has been reported by Perez-Gándaras and Zamorro (MS 1990).

## Discussion

The results allow us to construct feed-back mechanisms between the biological parameters of feeding of the cod population and their effect on year-class size. There are, of course, many other mechanisms underlying the recruitment patterns. For example, it is known that the formation of year-classes in general depends strongly on survival conditions during early life, i.e. through the embryonic, larval and fingerling stages. However, here we suggest it is possible to relate the feeding problems of a year-class (young and adults) to their reproductive variability and hence the subsequent year-class size variation. The mechanisms proposed here are: individual cod of a poor cod year-class feeds more than that of a strong year-class. This implies that the former has better feeding conditions. The better conditions could then produce more favourable weight-at-age or size-at-age, both of which can improve fecundity and/or reproductive variability (number and quality of eggs). This also implies that this phase of the cycle is closed, with a higher survival probability in comparison with more abundant year-classes.

It is obvious that there are many poorly studied problems behind each step of this proposed model. For example, according to Serebryakov (1990) there is no close relationship between population fecundity and subsequent recruitment in the Baltic cod. However, we refer to the reproductive variability in each year-class, not to stock fecundity as a whole. Similarly, Rijnsdorp *et al.* (1991) reported that the

TABLE 1. Total and partial fullness index for the two main food items. Atlantic cod by age groups in Flemish Cap, July, 1989.

Numbers	Age group								
	1	2	3	4	5	6	7	8	9+
Hyperiidæ (PFI)	.233	.341	.826	.755	.382	.056	.026	–	–
<i>Sebastes</i> sp. (PFI)	–	–	.021	.348	.592	1.568	.826	2.527	–
TFI		.527	.551	.941	1.292	1.183	1.940	2.016	2.527
1.250									
% Hy.+ Seb.	44.2	61.9	90	85	82.3	83.7	42.3	100	–
Number stomachs	7	7	242	467	387	55	9	8	2
% empty stomachs	14.3	14.3	4.5	6.2	10.1	0	0	0	–

TABLE 2. Total and partial fullness index only for the two main food items. Atlantic cod by age groups in Flemish Cap, July, 1990.

Numbers	Age group									
	0	1	2	3	4	5	6	7	8	9+
Hyperiidæ (PFI)	.864	.787	1.207	1.566	1.524	1.523	.370	.034	.006	–
<i>Sebastes</i> sp. (PFI)	1.885	–	.016	–	–	.115	.968	2.382	1.712	–
TFI	4.60	1.168	1.472	1.661	1.71	1.90	1.758	2.453	1.731	1.063
% Hy.+ Seb.	59.9	67.4	83.1	94.3	89.1	86.2	76.1	98.5	99.2	–
Number stomachs	14	30	85	44	106	103	86	28	17	17
% empty stomachs	0	3.3	0	0	2.8	1.9	0	0	5.9	–

conditions for growth vary substantially between years, but are independent of stock size for the North Sea cod. In the case of Flemish Cap cod, an increase in average length-at-age occurs when stock size decreases (Wells, MS 1983). In general, although there is insufficient information to test the model at each step, several publications provide provisional support.

Kjesbu (1989) studied the spawning activity of cod and found a positive correlation between egg diameter and female length. This demonstrated that growth is positively related to reproductive variability in cod. Also according to Walsh *et al.* (MS 1986), during the 1978-85 period on the Flemish Cap, on average one-third of the mature females did not spawn; and this was thought to be probably related to the poor quantity and quality of their food. Waiwood (1982) indicates that in mature females, fecundity is related to growth during June to September. With respect to the Barents Sea cod, Woodhead and Woodhead (1965) concluded that feeding condition (and hence growth) in the summer prior to spawning could influence fecundity in the next spawning season. In this way, much of the individual variability in relative fecundity encountered in nature can be explained by differences in summer growth. Also Wells (MS 1986) showed that egg numbers in Flemish Cap cod are significantly related to length, gonad volume and liver volume.

In short, it can be proposed that density depen-

dent reproduction (Ware, 1980) in Flemish Cap cod operates in conjunction with density dependent growth as a buffer mechanism for year-class size variation. However, specific studies about fecundity variations and the reproductive variability in the Flemish Cap cod are necessary to test our hypothesis.

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